



EXPLOSION (N.):

**A LOUD NOISE AND THE
SUDDEN GOING AWAY OF
THINGS FROM THE PLACE
WHERE THEY HAVE BEEN**

*~The Chemistry of Powder & Explosives
by Tenney L. Davis*

To test whether a travel-toothpaste-tube-sized bomb could bring down an airliner, Los Alamos scientists tried to blow a hole through half-inch-thick aircraft-grade aluminum using an explosive they developed. As seen by the approximately 5-inch hole in the blast plate pictured at left, their efforts were successful. (Photo: Los Alamos)

EXPLOSIVE RESULTS

LOS ALAMOS LEADS EXPLOSIVES-SCIENCE RESEARCH

Scientists at Los Alamos are solving national security challenges, from the threat of toothpaste bombs on airliners to ensuring the safety of our nuclear stockpile.

In February 2014, the U.S. Department of Homeland Security (DHS) got wind of a potential new bomb threat: explosives packed into a toothpaste tube that a terrorist planned to smuggle onto an airplane headed for the Winter Olympics at Sochi, Russia.

Could someone make such a small bomb and blow an airliner full of passengers out of the sky?

With no time to waste, scientists in the Explosive Science and Shock Physics division at Los Alamos National Laboratory leapt into action. In approximately 24 hours they tested an explosive they developed and called back with the answer: Yes, a toothpaste bomb was possible—“very possible,” in the words of Lab explosives researcher Bryce Tappan, who responded to the inquiry. And it could bring down an airliner.

Ever since the Manhattan Project, maintaining the safety, security, and reliability of the nation’s nuclear stockpile has driven multidisciplinary explosives research at Los Alamos.

Understanding the nature of the toothpaste-bomb threat was a “how-do-you-make-it?” problem. That kind of explosives research is just one piece of the Lab’s A-to-Z range of capabilities, most of them interrelated and synergistic and necessary to solve challenges to U.S. national security. As Tappan points out, Los Alamos has more scientists studying things that go *kaboom!* than anyplace in America and quite possibly the world.

That’s why national security and defense experts turn to Los Alamos. The Laboratory has been blowing up materials and studying the results for a long time. Los Alamos burst into the public consciousness 70 years ago with the biggest explosion known to humanity—the world’s first atomic bomb. That breakthrough required Manhattan Project scientists to understand the behavior of the conventional explosives that detonated a nuclear weapon, particularly in developing the uniquely shaped charges necessary to create a critical mass of plutonium in the implosion bomb design. Ever since the Manhattan Project, maintaining the safety, security, and reliability of the nation’s nuclear stockpile has driven multidisciplinary explosives research at Los Alamos.

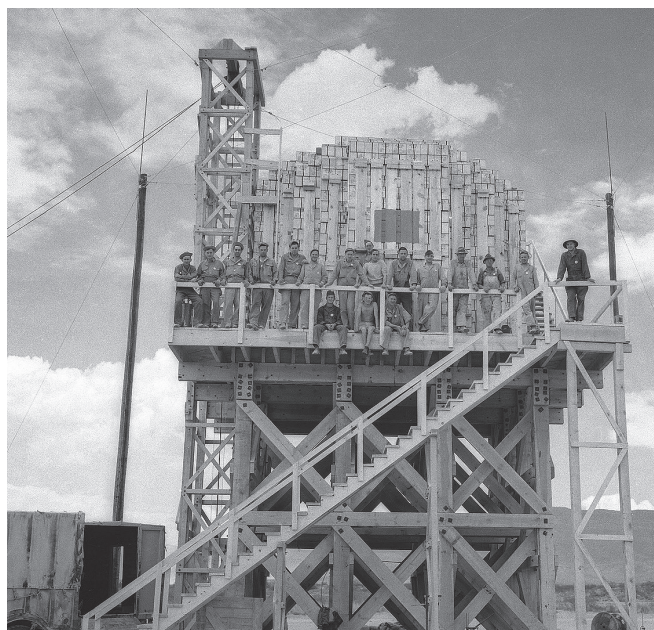
Not the Sensitive Type

Through the decades, much of the Lab's Department of Defense (DoD)-related research has centered on high explosives. This work includes synthesizing thermally stable, hard-to-accidentally-detonate (insensitive) explosives, which make for safer military munitions. (See "" on page 18.) In fact, in 1952 Los Alamos developed the first plastic-bonded explosives, which bind explosive powder with plastic to enable better control over the safety and performance characteristics of explosives. After a number of accidents involving nuclear weapons in the 1950s and 1960s (see "Learning from (Near) Disaster," page 16), the call to improve their safety led Los Alamos to develop insensitive high explosives and to patent the manufacturing technique for TATB (triaminotrinitrobenzene), the key ingredient in the insensitive high-explosive charges used to set off nuclear weapons.

The increased need for explosives in the wars following 9/11 and a focus on increased safety prompted the DoD to ramp up its demand for TATB.

Today, TATB is the only insensitive high-explosive molecule approved by the Department of Energy (DOE) for nuclear weapons. Conventional munitions use TATB, as well. By the late 1980s, decreased nuclear weapons production and the end of the Cold War led to a halt in TATB production, but the increased need for explosives in the wars following 9/11 and an ever-present focus on increased explosives safety recently prompted the DoD to ramp up its demand for TATB. Given the Lab's deep background with the material, Los Alamos played a critical role in a nationwide project to start making TATB again over the past 10 years.

In related work, Laboratory scientists are exploring revolutionary new methods of fabricating insensitive high explosives using 3D printing. Also called additive manufacturing, 3D printing allows for the rapid production of insensitive high explosives into complex shapes that would be impossible to make using traditional machining techniques. This technique will also give Los



Los Alamos has been in the explosive science business since the 1940s. The men on this test tower pose in front of the mountain of TNT used in the May 7, 1945, 100-Ton Test—which held the record as the world's largest blast until the Trinity test two months later. (Photo: Los Alamos)

Alamos scientists increased control over the explosives' safety and performance.

Meanwhile, the DOE's Stockpile Stewardship Program has been refurbishing the nation's aging nuclear weapons and the DOE has consistently emphasized continuous safety improvements for explosives used in the stockpile. Using TATB has a big impact on increasing overall nuclear weapons safety.

Lab scientists also tackle practical battlefield challenges, such as researching and testing explosives used in the deadly improvised explosive devices (IEDs) that characterize recent wars. Understanding the nature of these homemade explosives (HMEs) helps the military (and law enforcement) detect, handle, and mitigate them. The Lab also communicates that understanding directly to military Explosive Ordnance Disposal technicians at its Advanced Homemade Explosives Course. (See "The Hurt-Locker School," page 3.)



Emerging Threats and Detecting Explosives

The Laboratory focuses much of its explosive science research on emerging threats and explosive detection. To highlight that focus, in 2015 the Lab established its Explosives Center and also rolled out the Los Alamos Collaboration for Explosives Detection (LACED). Becky Olinger, the center's associate director and program manager at LACED, says new threats cover a broad spectrum beyond countering IEDs. For example, as with the toothpaste bomb threat, the Lab analyzes intelligence information to evaluate the plausibility of potential threat scenarios. "We look at whether these scenarios are a concern and, if so, how do we deal with them?" she says. Threats could include nuclear weapons, HMEs, or conventional explosives. If one seems legitimate, the Laboratory develops a countermeasure.

We are end-to-end, from design and synthesis to supercomputer modeling and testing.

Countermeasures include improving explosives detection. Los Alamos scientists and engineers are doing basic research on new technologies for detecting every conceivable type of explosive in a range of scenarios and then engineering new mitigation technologies for them. That research involves determining the chemical signatures of materials—necessary for developing a detection method—and inventing new methods to neutralize them.

In one example, David Moore of the Laboratory's Explosive Science and Shock Physics division recently led a team that created a radically new technology for detecting explosives from a safe distance. Called ODD-Ex (optimal dynamic detection of explosives), it zaps a suspicious material with a laser and then identifies it by analyzing the reflected light spectrum. Every material has a unique identifying signature of absorbed and reflected light. ODD-Ex combines greater

sensitivity than other related techniques with the ability to filter out interference from dust in the atmosphere, say, or other materials mingled with the explosives that can conceal the material's identity. The high sensitivity enables greater—and thus safer—standoff distance for interrogating a target such as a roadside bomb.

What's Next? The Future of Explosives Science at Los Alamos

No place else can match Los Alamos's suite of capabilities in explosives science and decades of experience: a deep roster of scientists doing research in the field, wide-ranging experience



Los Alamos explosives scientists are developing 3D-printing techniques to rapidly produce insensitive explosives in a wide range of shapes that cannot otherwise be created. Three-dimensional printing also gives increased control over the explosives' safety and performance. (Photo: Los Alamos)

Researchers at Los Alamos heat an explosive compound past its melting point, then pour it from the kettle into an apparatus to do experimental work. Explosives that melt at temperatures well below their ignition points—the temperature at which they blow up—can be safely poured into containers or molds without risk of detonation. (Photos: Los Alamos)



in explosive materials and every kind of detonation, facilities for developing and testing explosives, and expertise in detecting them.

To back up that claim, Explosives Center director Dan Hooks cites metrics such as the larger numbers of explosive tests conducted, papers published, and patents received. He also points to the Lab's exclusive facilities, such as its one-of-a-kind outdoor firing range. (See "Questing for the Holy Grail of High Explosives," page 15.)

"What's unique about Los Alamos in explosives science and research is that we are end-to-end, from design and synthesis to supercomputer modeling and testing, and from detection to characterization," says Olinger. "We cover the full gamut of explosives types, with all the experts on site, and bring real ingenuity to the problem."

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Even with the Laboratory's long, celebrated history of explosives research, Hooks thinks the best work is yet to come. "In explosives, we're in a time of major transition," he says. "We

have the tools to see things now that we've only been speculating about for 70 years, so there will be a generational shift in making new materials, knowing how they will respond, and understanding what drives that response."

Advances in basic science—the theories underpinning research—fundamental diagnostic tools, and computing platforms will enable Lab scientists "to see what's going on in a material—the physics and chemistry—almost in real time," Hooks says. "We'll be able to take a snapshot of picoseconds [millionths of a second] resolved to microns [millionths of a meter] or less. Once we can see something happening, that changes the theory and that changes the model. We'll have a new ability to make things and predict things. These breakthroughs will lead to a fundamental improvement in the safety of rockets and weapons. We're developing the future right now. In 15 to 20 years, it will be a whole new world of explosives science."

Of course, global events will also shape that future. Although the nuclear mission will remain central at Los Alamos and a driver of explosives science, Hooks says, threats such as IEDs and HMEs "will continue to be a challenge in any theater."

No one really knows what the next new threat will look like—or where it will come from. But Los Alamos will be ready to help fend it off. ✦

~Charles C. Poling



Los Alamos conducted more than 400 high-explosive-driven experiments in 2015. (Photo: Los Alamos)